

The Landscape of Isolated DC/DC Bias Power Supplies

Moving signals and power across an isolation barrier is a common challenge for designers. Isolation might be required for safety, noise immunity or large potential differences between system domains. Understanding system-level specifications like the number of outputs, regulation requirements, output power, insulation rating, operating temperature and input voltage range are critical. From there, designers can derive the lowest-cost solution that meets all of the system requirements. **Ryan Manack, Business Lead, Texas Instruments, USA**

For example, a cellphone charger is internally isolated to prevent humans from becoming electrically tied to the mains if the connector short-circuits. In factory robots, sensitive control circuitry sits on a separate ground and is isolated from the motors that draw large DC currents and create noise and ground bounces. Communication and sensing are commonly implemented across an isolation barrier.

Traction inverters and motor drives take a PWM signal from the motor controller and pass it through an isolator to tell the gate driver to turn a power transistor on or off. Isolated bias converters enable isolated communication and sensing by providing bias power from one side of the isolation barrier to the other. Current and voltage sensors, digital isolators and gate drivers typically require less than 15 W and as little as tens of milliwatts of power. Figure 1 shows an example of each of these applications.

Isolated DC/DC bias supply requirements

There are many solutions that can provide

isolated bias power, from controllers, which have external power switches, to converters, which integrate a controller with power switches, to finally power modules, which integrate controllers, power switches and transformers in one package. Because of this wide variety of bias power solutions and diverse applications that they go into, it is important to fully understand the

application requirements in order to meet the specifications at the lowest cost.

At a minimum, the designer should understand the bias supply input voltage range, the output voltage and the output power requirements. Some applications will require more than one bias voltage so it is important to define the acceptable regulation for each output. System requirements such as insulation rating,

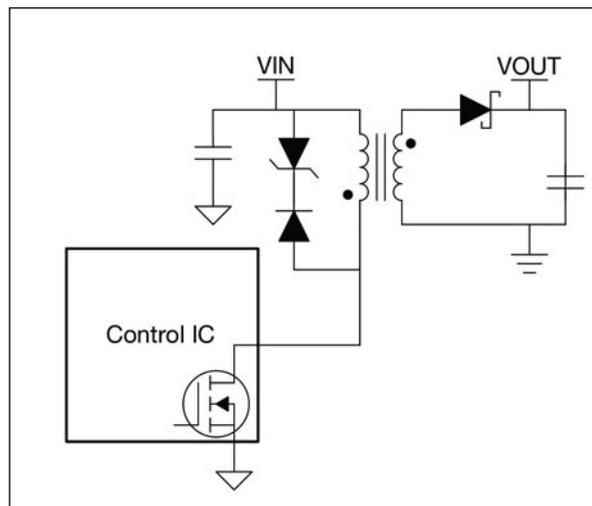


Figure 2: Simplified schematic of the flyback converter

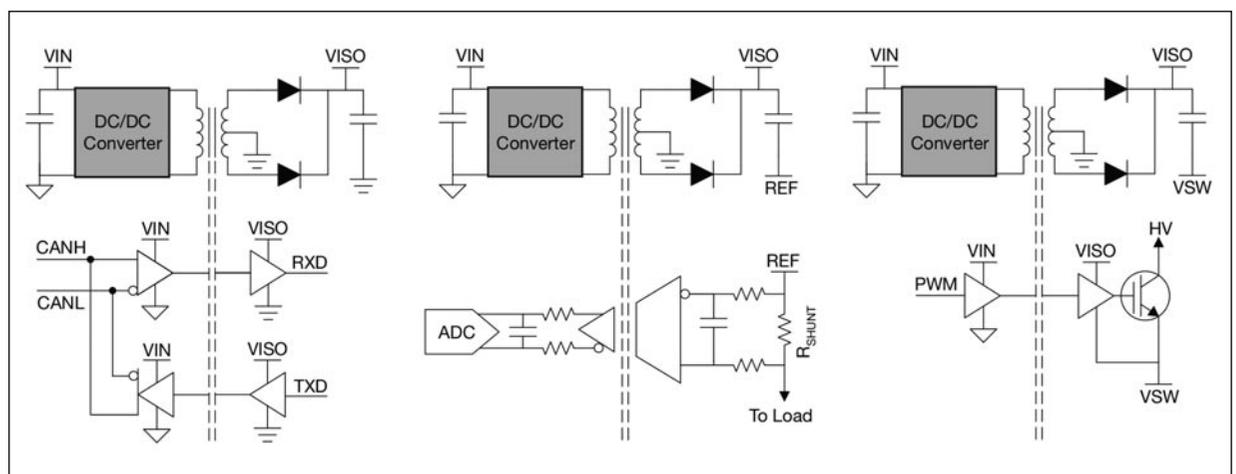


Figure 1: Isolated bias applications

ambient operating temperature range, electromagnetic interference (EMI) and electromagnetic compatibility (EMC) will further drive design decisions. Let's review some example isolated bias supply topologies.

Flyback converter

The flyback converter is a well-known topology that has been widely used for decades. This power converter can support a wide variety of applications due to its flexibility and low cost. Advancements such as FET integration and primary-side control make this topology even more attractive.

Compared to buck-derived topologies like forward, push-pull and half-bridge, the flyback topology requires only one primary switch, one rectifier and one transformer-like coupled inductor (Figure 2). When the primary switch is on, the input voltage is applied across the primary winding, storing energy in the transformer's air gap. The output load is supported only by the output capacitor in this state. When the primary switch turns off, the energy stored in the transformer is delivered to the secondary through the rectifier to supply the load and recharge the output capacitors.

A flyback converter performs well as a bias converter for a number of reasons. It provides regulation and isolation in one conversion stage. Its flexibility is also useful for multiple outputs. The number of output windings and wind the transformer support a chosen configuration.

The corresponding voltage on the output windings is a function of the duty cycle and the primary-to-secondary windings' turns ratio. It is also possible to reference each output to a different ground in order to meet system isolation requirements. Other flyback benefits include its relatively low cost and wide

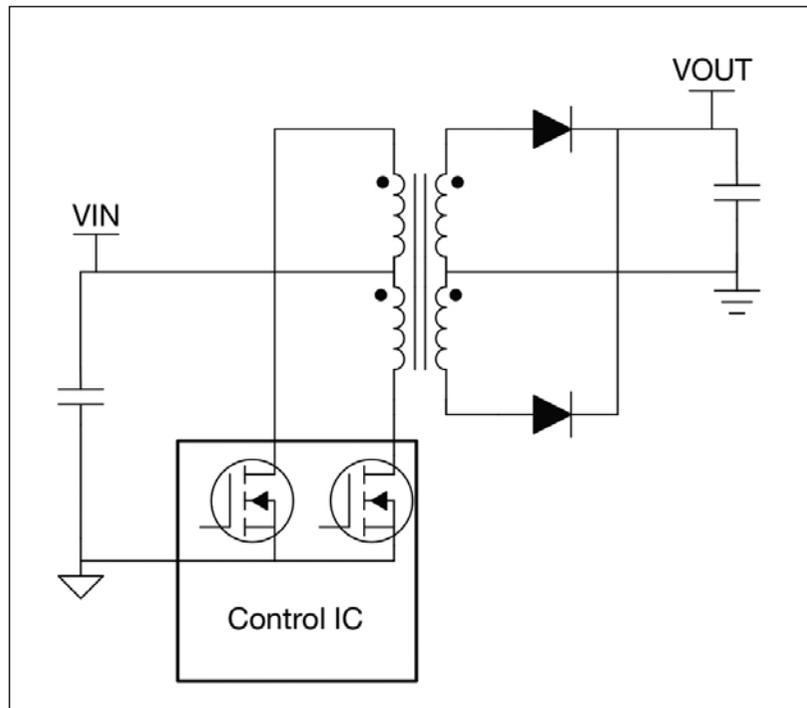


Figure 4: A push-pull transformer driver

input-to-output operating range.

It is important to properly design a flyback transformer for best performance. The transformer should be very well-coupled, with low leakage inductance for the highest efficiency and best regulation, especially in multiple outputs. However, it is also necessary to limit the parasitic capacitance from the primary to secondary in order to prevent excessive EMI.

Fly-Buck converter

A Fly-Buck converter is a TI-specific topology used to create an isolated bias supply. It is capable of operating from input voltages as high as 100 V. Like a flyback converter, MOSFETs are typically integrated inside the IC, and it is very

simple to realize primary-side control (Figure 3). The topology uses a synchronous buck converter with a coupled inductor to create one or multiple isolated outputs. When the high-side switch is on, the primary side works like a buck converter and the secondary winding current is zero. In the off-state when the low-side switch is on the secondary side is driven from energy stored in the primary.

Synchronous buck converters are widely available, making the Fly-Buck converter an attractive topology. The converter does not require an additional auxiliary winding or optocoupler for control as the feedback loop can be closed on the primary output voltage. The coupled-inductor construction is flexible. The turns ratio, insulation rating, number of secondary windings and PWM duty cycle are controllable for use in a wide variety of applications.

Like the flyback converter, the coupled inductor must be properly designed. It is important to manage the leakage inductance while limiting the parasitic capacitance from primary to secondary. For applications requiring greater than 100-V inputs, a Fly-Buck converter can be used with an external MOSFET.

Push-pull transformer driver

A push-pull transformer driver is a commonly used solution for low-noise, small-form-factor isolated power supplies. It is supplied from a tightly regulated input rail and operates in an open loop at a fixed 50 % duty cycle. MOSFETs are integrated into the IC, enabling a compact solution (Figure 4). The push-pull topology is a

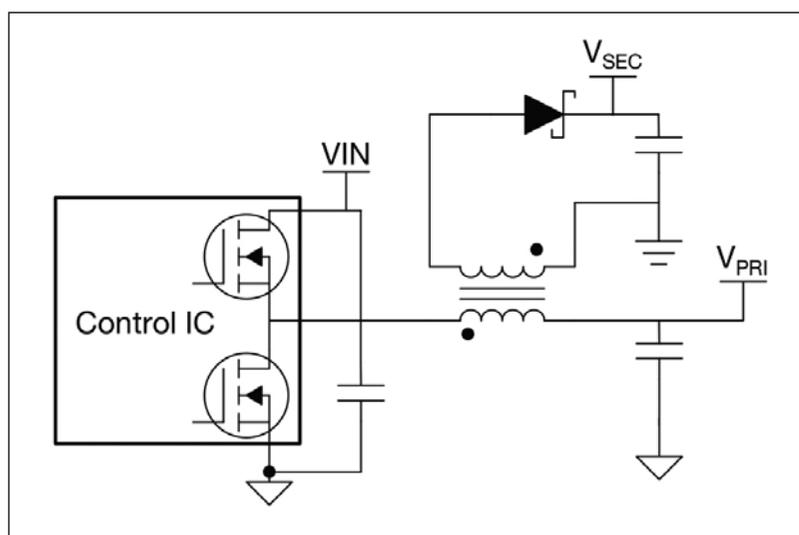


Figure 3: A Fly-Buck™ converter

double-ended variant of the forward topology with both MOSFETs ground-referenced, eliminating the need for external bootstrap circuitry. Similar to the single-ended forward converter, the voltage stress at the FETs is two times the input voltage. The MOSFETs switch at a 50 % duty cycle during alternate half cycles, driving the center-tapped winding of the transformer.

The push-pull transformer driver is a prevalent isolated bias power-supply solution for many reasons. It offers flexibility and the ability to support multiple outputs. The open-loop configuration provides design simplicity by eliminating the feedback loop. The push-pull transformer offers lower primary-secondary capacitance, which enables a reduction in common-mode noise compared to flyback and Fly-Buck converters. Additionally, the push-pull topology more efficiently uses the transformer core magnetizing current, resulting in a smaller magnetic solution compared to flyback and Fly-Buck converters.

Although the transformer driver carries a number of advantages, it is also important to take into account the trade-offs. Unlike the flyback and Fly-Buck converters, the transformer driver cannot support a wide input voltage range, and instead requires a tightly regulated input voltage.

Meeting the output-voltage regulation requirements for feedback can be challenging due to the absence of a closed loop and may require a low-dropout post-regulator (LDO).

Power modules

Power modules have existed for decades. These solutions are widely available and offer significant integration compared to discrete implementations. Power modules exist in many varieties, with input voltage, output voltage, output power, number of outputs,

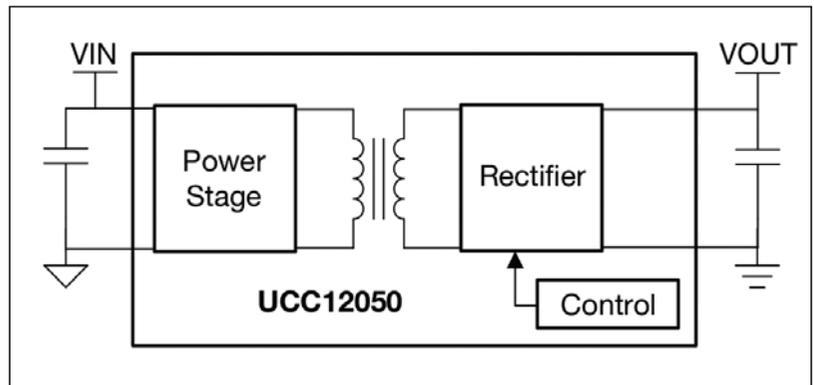


Figure 6: UCC12050 isolated DC/DC bias power supply

isolation rating and regulation options. Figure 5 shows the block diagram of the inner workings of one power module. The topology includes a transformer driver similar to the discrete version. Some devices may integrate an output LDO for regulation.

With many options available, a power module can be used in most isolated bias converter applications. They greatly simplify the design process because there is no need to specify, design or choose a transformer; to include an input and output decoupling capacitor is sufficient to start the design. Other options like synchronization, output voltage selection, enable and error signaling are available as well.

Some flexibility with modules will be lost, specifically to configure the number of outputs and transformer turns ratios. The selection of modules rated for a 125°C ambient temperature range is less than for the 55°C and 85°C options. Similarly, the number of modules available with fully reinforced insulation ratings is less than those modules available with functional or basic isolation.

A next-generation bias solution

Innovations in transformer design and higher frequency topologies have

enabled IC designers to integrate a transformer and Silicon into one IC. For the end user a small, lightweight isolated DC/DC bias power supply is available without having to design a transformer or compromise on system performance.

Figure 6 shows the block diagram of the UCC12050. Though it looks similar to a power module with integrated power stage and rectifier, a closer look at the operation shows that the switching frequency is much higher compared to power modules. This allows significant height and weight reduction versus lower switching frequency alternatives. The internal topology control scheme runs closed-loop without an LDO or external feedback components.

The UCC12050 brings many benefits to the wide variety of isolated DC/DC bias supply applications. It is designed with an EMI-optimized transformer with only 3.5 pF of primary-to-secondary capacitance and a quiet control scheme. On its own the solution can pass CISPR32 Class B on a two-layer PCB without ferrite beads or LDOs. The device is rated for reinforced isolation of 5 kVrms and 1.2 kVrms working voltage and will operate at 125°C ambient temperature. The family of devices also includes UCC12040, which is rated for basic isolation of 3 kVrms and 800 Vrms working voltage.

UCC12050 is targeted for 5-V input, 3.3-V to 5.4-V output applications requiring 500 mW. Applications requiring higher input or output voltages will need to provide pre-or-post conversion. Also, for designs requiring power above the UCC12050's derating curve, alternative topologies should be explored.

Literature

Power Through the Isolation Barrier: The Landscape of Isolated DC/DC Bias Power Supplies; Texas Instruments, APEC 2020 Presentation.

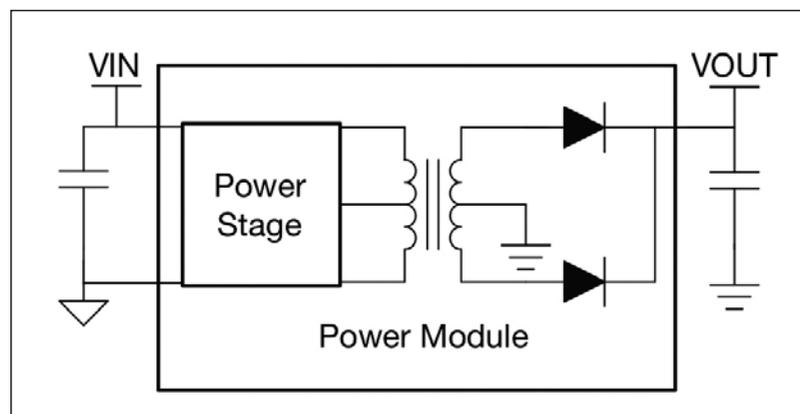


Figure 5: Block diagram of the inner workings of a power module